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The activity of information in biomolecular systems: a fundamental explanation of holonomic brain theory

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Abstract

We wish to suggest a mechanism for binding intrinsic information based on an inter-cerebral superfast, spontaneous information pathway involving protein-protein interactions. Protons are convenient quantum objects for transferring bit units in a complex water medium like the brain. The phonon-polariton interaction in such a medium adds informational complexity involving complex protein interactions that are essential for the superfluid-like highway to enable the consciousness process to penetrate brain regions due to different regulated gene sets as opposed to single region-specific genes. Protein pathways in the cerebral cortices are connected in a single network of thousands of proteins. To understand the role of inter-cerebral communication, we postulate protonic currents in interfacial water crystal lattices result from phonon-polariton vibrations, which can lead in the presence of an electromagnetic field, to ultra-rapid communication where thermo-qubits, physical feelings, and protons that are convenient quantum objects for transferring bit units in a complex water medium. The relative equality between the frequencies of thermal oscillations due to the energy of the quasi-protonic movement about a closed loop and the frequencies of electromagnetic oscillations confirms the existence of quasi-polaritons. Phonon-polaritons are electromagnetic waves coupled to lattice vibrational modes. Still, when generated specifically by protons, they are referred to as phonon-coupled *quasi-particles*, i.e., providing a coupling with vibrational motions. We start from quasiparticles and move up the scale to biomolecular communication in subcellular, cellular and neuronal structures, leading to the negentropic entanglement of multiscale 'bits' of information. Espousing quantum potential chemistry, the interdependence of intrinsic information on the negative gain in the steady-state represents the mesoscopic aggregate of the microscopic random quantum-thermal fluctuations expressed through a negentropically derived, temperature-dependent, dissipative quantum potential energy. The latter depends on the time derivative of the spread function and temperature, which fundamentally explains the holonomic brain theory.

Keywords: Quantum potential chemistry; quantum-thermal fluctuations; thermo-qubits; intrinsic information; Grotthuss mechanism; negentropic gain; quasi-polaritons; protons; dissipative quantum potential energy; resonance; holonomic brain theory.

1. Introduction

Consciousness has been wrongly interpreted based on phenomenology as a higher-brain function and unitary in its action because of the metacognitive approach taken to understand consciousness. The cognitive neural networks of the brain are not syncytial structures, and there is a reason for this. It allows the brain to apply Hebbian learning in cognitive settings. However, synaptic pathways are plastic and not suitable for the consciousness process to be malleable. Even in psychiatric conditions like schizophrenia, the brain chemistry related to cognitive function falters, not consciousness [1]. Moreover, psychological studies using brain imaging fuel the fire by misconstruing consciousness with cognition and justify their confusion by defining "conscious cognition" [2].

Often it is said that consciousness is about bringing things together so that the brain has an overview of itself and the world. This phenomenological description is the century-old dogma of the so-called "unity of consciousness". Since William James first mentioned it in 1900, psychologists have taken it for granted. Today, adherence to the integrated information theory of consciousness utilizes the dogma for the avoidance of two or more consciousnesses [3]. Generally, it stems from the misunderstanding of consciousness as a metacognitive phenomenon and not a multiscale process.

Moreover, consciousness has been referred to incorrectly as a higher brain function [4]. To undo this mistake, it is noted that consciousness is a holistic brain function arising not from a higher level but the quantum-thermal fluctuations at the molecular scale acting as an "*integrator*" of non-integrated intrinsic information through a '*negentropic force*. Without articulating quantum entanglement, we postulate *inter-cerebral superfast, spontaneous information pathways based on*

polaritons. The word "integrator" should not be confused with "integrated". We are dealing with the non-integrated theory of consciousness, referred to as the disintegrated theory of consciousness [5,6].

Deciphering how the brain codes consciousness rests primarily on its physical basis, secondarily on the binding problem via possible nonlocal holonomy and on the first-person perspective (1pp) expressed through phenomenology. The binding problem (or combination problem) concerns the brain's capacity to encode information across time and cortical space (e.g., [7,8]). Nonlocal holonomy invokes an interplay between thermal ordering and structural discontinuities induced through information-based (negentropic) action. This essentially leaves the possibility for nonlocal holonomy and negentropic action to be associated with the metamorphosis of consciousness process as physical feelings [6] arising from the delocalization of electronic signaling in hydrophobic regions of neuronal membranes, proteinaceous structures of the microstructure and its continuation through protein-protein interactions across the cortical regions. This includes subcortical regions like the hippocampus and thalamus through ultra-rapid, long-range correlative communications based on proton conduction, as suggested by the quantum extension of the classical *Grotthuss mechanism* [9]. A more critical attitude, promoting conventional prototropic hopping mechanisms, was advanced by [10]. However, the study did not offer concrete evaluations of the cardinal investigations [11]. Recent research on Grotthuss shuttling in biological systems [12] has been advanced [13].

Panexperiential materialism [14] stands at the crossroads of neuroscience, quantum mechanics, and philosophy as a transdisciplinarity. At its core is the premise that the intrinsic information of the material is experiential, leading to organismic panexperientialism. What is intrinsic information? According to [15]:

"*Intrinsic information is physics information such as the microphysical properties of the constituent elementary particles and, for instance, the basic genetic information. It is a modality of energy*."

As a modality of energy, it can be defined as the patterns associated with constrained energy processing. Still, it is not a form of energy, as it should include an account of the entropic situation. In addition, under the auspices of multiscale intrinsic information, it becomes meaningless to suggest such information without further analysis, e.g., being meaningful, for instance, after the reception, perception, and representation and/or this information can be transferred in various ways and levels. Intrinsic information should be coupled to entropy lowering, compensating entropy production at steady state conditions and not as general knowledge for the whole organism, even if it is multiscale (cf. active information [16].

We will approach intrinsic information from the steady-state situation of structural order through fluctuations (e.g., [17]), where the information is essentially authorized and matched by the acquired entropy production. This is closely yet different from quantum information theory [18]. In both cases, one might exorcise a Maxwell Demon. Landauer's erasure principle defines entropy measures specifying the information and uncertainty given to any observer, escaping the observer dependency by including a standard observer. The minimum amount of energy to erase one bit, the Landauer limit, is attached to temperature via the general entropy formula and Boltzmann's constant. The short discussion on Landauer's principle is quite important since the addition of temperature erases an information 'bit' in a somewhat *ad hoc* way. In our introductory presentation, we alleviate Wheeler's dictum "it from bit" with" bit from it". We employ a bottom-up strategy that establishes the '*bit from it*' via proper thermalizations of the system density matrix at precise temperatures and time scales, which clearly distinguishes intrinsic information from Landuer's quantum information in which the standard application and implication of Brillouin's/Landauer's principle are no longer valid [19].

In contrast, our protocol concerns the activity of information or information-based action, cf., the ideas discussed in [20]. This suggests that the meaning or semantic aspects of information (ignored in Turing computation) are brought about through energy transduction (see [6]). The process of activity of information produces evanescent meanings that are context-independent but are actively used to change the state of the physical system. This is *non-Turing computation*. Proceeding, we advocate the steady state situation, where the production of entropy/uncertainty matches the conditional entropic gain as a '*quantum of information'*. Pribram [21] was the first to incorporate complexity and thermodynamics in terms of a "*quanta of information*" as an ensemble of minima of least entropy. Keeping intrinsic information non-integrated necessitates a steady state situation, where the entropy production balances syntax forming negentropic gain in accordance with the second law of thermodynamics. Intrinsic information is non-integrated and irreducible; therefore, there is no flow of information, as Eccles [22] suggested, which is necessary for the negentropic action resulting in a negentropic force to create information. Negentropic entanglement transforms the non-integrated intrinsic information through a negentropic force that is spatially ongoing without dissipation [23], thus, serving a

functional role of ensuring the interoperability of non-integrated intrinsic information to a higher level (see [6]).

One might say that *energy processing is "hard-wired"* into the brain, which somehow organizes consciousness [24]. Piaget's theory of cognitive development involves processes based upon actions and, therefore, is a basis for "intrinsic information" across scale, which designates information-based action as its modus operandi. The physical basis of consciousness depends on the inner process of negentropic action absent from phenomenological states. Environmental interactions influence the dynamics of the quantum chemical system modifying quantum mechanical applications, such as, e.g. the standard virial relations of pioneering quantum chemistry between the kinetic and the potential energy. The subsequent energy transition defines the *information-based action* due to the 'gain' of intrinsic information, for instance, interpreting this as a neuropsychodynamic mechanism related to a partially holistic molecule [25]. The information of partially holistic molecules refers to the action of giving form to partially holistic molecules. The intrinsic information is transduced as negentropic action through Brillouin's negentropic principle of information [26,27] and the notable historical work [28].

Interesting structures, such as microtubules, have been theorized to play an important role in consciousness [29]. No doubt, they might play important roles under specific conditions. However, the definition of Tubulin qubits requires, e.g., complex enzymatic switching mechanisms yet to be experimentally proven [30,31]. To understand the role of inter-cerebral communication, we might extend this assumption to molecular-based quasi-polariton models recently proposed by [32] to formulate appropriate quasiparticle interactions emulating the origin of intrinsic information encoding based on molecular thermo-qubits.

The holonomic brain theory [21] suggests information is stored in interference patterns among wavefronts observed in presynaptic arbors of dendritic trees, created by differences among phases in the spectral domain as a holonomic brain process of experiences. In particular, it posits how nonlocal functional interactions in cortical processing can explain nonlocal holonomy differently from the microscopic '*spooky-action-at-a-distance*'. Yet, the holonomic brain theory is incomplete. The basis of holonomic brain theory is similar to quantum events. The holonomic brain theory is not analogous to quantum theory; rather, its formalism obeys the same rules as quantum mechanics. However, the distributive processes at the neural level, such as the distribution of ionic charge that can be identified with those described in the quantum domain, do not imply that neural processes are quantum mechanical. This is a caveat in Pribram's approach, as he could not illuminate the quantum-like computations in his theory. However, the approach attempts to explain the holonomic brain theory in terms of quantum-like aspects of the submolecular scale. We have considered delocalized electrons in partially holistic molecules as a substrate for quantum-like processes in conjunction with protons and phonon-polaritons.

Few studies have attempted to unify the Bohmian-type models based on the ontological formalism of hydrodynamic quantum mechanics with a holonomic formalism [33]. Such a relation is unsatisfactory because the resultant 'hidden variable' known as the neural quantum potential, is dependent on macroscopic variables that are without ontological interpretation. The physical meaning of the parameters depends on *ionic bioplasma* in a general context but [33] did not examine the scale beneath neurons where information is transported with quantum degrees of freedom, such as polaritons, phonons and protons.

2. Resonance in EM workspace

An electromagnetic (EM) resonance theory of consciousness is the shared vibrations by which rudimentary consciousness is unified [34]. We believe that this theory is incomplete. Although [35] have proposed that ALL theories of consciousness are EM theories of consciousness and that the actual explanation will come from a generalized account of how EM delivers a 1pp, there is insufficient evidence suggesting global inter-cerebral communication of information based on London forces' collective electron charge movements that may influence protein conformational changes [36]. On the other hand, aromatic rings produce photon emission whenever the electron accelerates while moving within the ring. The photons are not dissipated but are absorbed by the phonons as quasi-particle phonon-polariton vibrations. Recent work by [37] has suggested that macroscopic 'long-range order' in brains ex ists only without classical potential energy. In other words, the self-amplification of quantum potential energy in the absence of classical potential energy plays a pivotal role in energy processing stemming the way for quantum potential chemistry [38] as the formalism of choice.

Light-harvesting has recently been considered a rigorous quantification of entanglement in biological systems [39]. Although the time scales and temperature ranges are quite modest, this is a very interesting result, employing estimates of the von Neumann entropy and providing a transportation wire for excitations in light-harvesting complexes. Photon-like waves are also present due to EM resonance in the π bonds of benzene rings that are common in the molecular structure of aromatic amino acid residues

[29,40], such as phenylalanine, tryptophan, and tyrosine (see **Fig. 1**). According to [41] photons form a coherent field protected against decoherence in the brain environment. Still, more likely, they become transduced through the interaction with phonons to be expressed as phonon-polariton vibrations.

A resonant EM energy transfer from the EM brain to the electro-ionic brain is part of the proto-conscious experience. Assume perceptions are cognitive and reflect as external excitation at a particular frequency, this can be described in terms of sensory or Shannon information. Next, assume intrinsic information can be described through phase dynamics with the same frequency. Such a match produces resonances that are holonomic effects enabling conscious perceptions to take effect in the global workspace. The Global Workspace Theory [2] theorizes that consciousness is created by pooling information via a "working space" that competes with Shannon's information concept, enabling the brain to be conscious of only one thing at a time. The neuronal workspace serves as a site for information exchange via classical transportation of information which is Turing computational. However, conscious cognition is non-Turing computational. According to panexperiential materialism [14], the mind is not "wired" to the brain but related to the dynamic processes of brain matter, i.e., the material composition of consciousness that relies on how EM delivers a 1pp.

Proceeding along the line of an EM field in the brain, one might mention the two-brains *hypothesis* [42,43], which claims that: (1) the electro-ionic brain is the domain of cognition, i.e., the ability to process information at the macro-level activity associated with cognitive neuro-computation. It is tangible, known and accessible, recognizable through the third-person perspective (3pp) and referred to as the "electro-ionic brain." Electro-ionic pathways are those where ionic flows dominate (e.g., ion-dipole interactions, ionic current flow in axons, large dendritic shafts, extra synapses), and (2) the EM brain is the domain of subtle energy transfer where the exchange of virtual biophotons creates a magnetic field between magnetic dipoles and electrostatic "Coulomb" forces [44]. The EM brain is inseparable (spatiotemporally) yet segregated functionally from electro-ionic activity. It is intangible, unknown and inaccessible but recognizable through the 1pp and is the domain of consciousness [23,37].

The main question arising in the 'two-brains' hypothesis [42] is the origin of the endogenous EM field at the molecular level and, more importantly, whether the magnetic field component generated by the endogenous EM field can be used as an information signal. There are no theoretical studies to our knowledge that develop multiscale signaling models with endogenous EM fields. By endogenous, we mean confined EM waves (cavities), not in free space. It is proposed that the energy transfer carries 'meaning' that modifies the *classical realm* as the functional part. In other words, the polariton may be a vehicle for transmuting quantum mechanical fluctuations to normal-level neural signaling [45]. It is conceivable that 'qualia' as the conscious aspect of subjective experiences [46] is influenced by the energy transferred from the EM brain to the electro-ionic brain. The transfer of energy from bare polaritons to quasi-polaritons involves ion-dipole interactions.

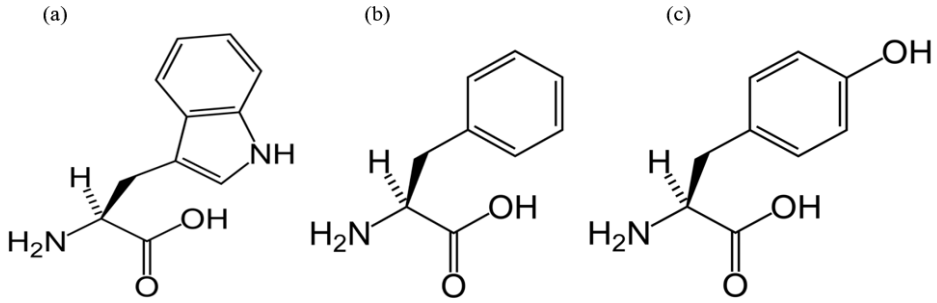

Fig. 1 *Aromatic amino acid residues comprise key portions of protein-protein or protein-ligand interaction interfaces on the protein surface: (a) Tryptophan, (b)Phenylalanine, and (c) Tyrosine. The residues in aromatic amino acids are benzene-like rings with resonant electron orbitals. Aromatic residues are nonpolar and 'hydrophobic' but have delocalized electrons, so polarizable dipoles can be induced by London dispersion forces, which drive protein folding into their functional shapes. Proteins, chains of amino acids, derive function from their shapes governed by van der Waals heterostructures, particularly aromatic residues by London forces in intra-protein 'hydrophobic' pockets.*

Hales [47] has applied classical electromagnetism in free space through Maxwell's equations to describe the endogenous EM field. Still, this is inappropriate as EM waves, and phonon-polaritons modes provide an accurate description. In the brain, the endogenous EM field at the molecular level is considered minuscule yet not completely absent, i.e., quasi-electrostatic conditions prevail [48]. Thus, minuscule can be interpreted to mean 'subtle'. Its presence is caused by an intrinsic property of charged particles endowed with the property called "*spin*", which is a quantum of magnetization. It can affect other magnetic dipole moments [49] regarding their sensitivity to the quantum phase shifts. The phase of the system is changed by the magnetic vector potential [44]. The phase of every coherent system becomes a 'memory' of the events occurring across the whole relation [50]. This is possibly how coherent information becomes a unified conscious field [51] through phase correlations between dipolar molecules without classical transportation of information. Such phase correlations are referred to as coherent molecular patterns of EM waves that may induce a '*biological order*' (see [52] for a review). The information accrued corresponds to a lower thermodynamic entropy, which becomes negentropy/order. Consequently, since entropy usually is associated with noise, i.e., implies random thermal motion of atomic and molecular constituents, its decrease will create a molecular organization [25], i.e., 'biological order'. Indeed, meaningful information is semantic [53], so it will be necessary to understand the content of consciousness better by identifying the informational structure.

The magnetic field energy due to the brain's magnetic field intensity generated by spontaneous currents is less than thermal noise energies. It hence cannot be expected to affect neural processes. This contrasts with the conscious EM information field (CEMI) theory, which claims that information within neurons is pooled to form a conscious EM information field [54]. CEMI theory requires the synchronous firing of large numbers of synapses on cortical pyramidal cells that oscillate at certain frequencies, thereby perturbing a global EM field external to them, creating in it a "pattern" representing neuronal information which feedbacks to the neurons as 'consciousness'[55].

This feedback is regarded as modifying the electric charge across membranes affecting how neurons will fire. The quantized endogenous EM field at the molecular level can invoke electric dipole oscillations. However, this quantum interference effect does not require a *strong magnetic field* to exist endogenously because it is not the intensity of the magnetic field but the interference shifts that describe the rhythm of oscillations of the field expressed in terms of periodicities of discrete energies (cf. [44]). Given that the strength of the endogenous EM field is local, a spatial EM field pattern encoding any given conscious experience would be undetectable at a short distance from where it was generated. This, in turn, means that neurons across the whole brain would not be "turned on" by these localized, putatively conscious EM patterns (see also [56]).

3. Quasi-polaritons as dipolar excitons in water crystal lattices

A quasi-polariton can be considered the strong coupling of the bare modes: the photon and the dipolar oscillation (phonon) in a crystal lattice of water molecules and ions. What inner process resulting from negentropic gain can then be meaningful? Furthermore, is this how meaning arises from subconscious physical processes that support conscious experiences? Shannon's information theory provides no knowledge regarding the definitive "states of the physical landscape" as determined by intrinsic information. The intrinsic information in the sense of physical transitions, encoded in the quasiparticles of the brain, is tuned to temperature and time scales under the constraints imposed by the structuring of the redundancies across scale where entropy production matches the negentropic gain in achieving the minimum possible entropies defined as an ensemble of minima of least entropy or a '*quantum of information' (minimum uncertainty)* [21]. The negentropic action entails a negentropic force, and if continuous, it points to *negentropic entanglement* or the 'binding' of intrinsic information necessary for consciousness [23].

The neologism "*negentropic entanglement"* (negentropic=relating to information in the sense of changing states of physical properties), i.e., intrinsic information (= change of states in the brain's material composition); entanglement=binding) should not be confused with quantum entanglement which emphasize the binding of quantum states between particles. The difference is that the former is fundamentally intrinsic in terms of thermo-qubits, and the latter is not intrinsic but exists in the connection between the particles. To establish negentropic entanglement, one needs to 'harvest' the steady-state situation [14,57].

The quasi-polariton model has a 1pp, a polaritonic-core (quasiparticle) attached to a third-person perspective (3pp), and cognitive elements— semi-classical dynamics of quantum lateralization. The raw quasiparticle core is not detectable, but only the outer core reflects on a route from the multiscale signaling structure of the brain to the quantum chemical properties suggesting the primitives of experience and meaning. The formulation rests on the precise open system dynamics of density matrices subject

to Liouville-Bloch equations. Therefore, to avoid contradictions [58], we will model quasiparticles as the proxy and basic ingredient, mimicking quantum neurobiology's extended density matrix formulation. This will make perfect sense as the quasiparticle model depends on the materialistic properties of the brain [22,59,60,61]. Attempts at unifying quantum analog models of subconscious energy processing with cognitive processing of ions and water molecules that realize these higher-level behaviours are under way based on quasiparticles as carriers of the 1pp [32].

Energy quantization brings about the emission of photons. Photons can induce energy level transition between vibrational energy levels (phonons), or when a molecule enters a high vibrational level and drops to a lower level emits photons associated with thermal agitation. The photon harvesting is carried out through phonon-polaritons interactions in water lattice crystals. This is different from conformational transitions, where the stretching and shortening of covalent bonds of molecules result in molecular vibrations. This is caused by molecular transduction in the receptor-ligand complex of an aromatic residue involving protein-protein interaction in the extracellular fluid. In the ligand, a single electric charge couples with an opposite charge through dispersion London forces. It is replicated across the entire proteinaceous networks generating an endogenous EM field within proteins. This is replicated in the intracellular domain to which the ligand was coupled. These residues acquire a synchronized effect due to an interconnection produced by the EM field.

Phonons, quantized lattice vibrations stemming from the crystal lattice structure of interfacial water, are quasi-particles or *collective excitations* responsible for generating and maintaining dipolar order and can involve the collective modes of oscillating dipolar fields and localized dipole moments throughout the brain. Vibrational *collective excitations* propagate to neighboring dipolar molecules due to dipole-dipole interactions. Interaction between groups of charges of the molecular dipoles in macromolecules manifests in vibronic motion with frequency. Each molecular dipole interacts with other molecular dipoles via intermolecular forces, e.g., dispersion forces; these interactions cause dipolar oscillations to spread with frequency into a narrow range and to provide energy exchange between molecular dipoles. The interaction between molecular dipoles within ordered water manifests in a collective vibrational excitation by transforming any incoherent or disordered quanta of energy into a distinct collective mode of excitations along the myriad of dipolar molecules [62,63]. Resonant energy transfer in macromolecular systems is referred to as conformational waves. They are excitations that can transport energy without net electric charge, representing a transient switch in the dipole moment (charge separation). The propagation of such conformational waves can induce a polarization density of interfacial water dipoles, causing a breakdown of the dipole rotational symmetry. This affects the conformational states in dipolar molecules and therefore coupling to conformational transitions (via a mechanism similar to protein folding) in crystal lattices of interfacial water molecules. Such conformational waves propagate via *tunneling* behavior within the crystal lattices of interfacial water molecules [64,65].

The functional role of crystal lattices of interfacial water molecules was shown to act as a conduit where energy is transferred like a dipolar laser [62]. The frequencies of dipolar fields are comparable to the coherent order of interfacial water dipolar molecules. This allows the dipolar laser to propagate between the interfacial water dipolar molecules, referred to as '*water lasing*' [66]. Georgiev & Glazebrook [67] estimated that water lasing within ionized milieu of ordered water is attained for 10^{-11} s, during which quantized excitation polarization wave up to 25 nm in size acts causally throughout the EM brain [68].

Vibrational excitation propagates to neighboring dipolar molecules due to dipole-dipole interactions. The excitation interacts with the hydrogen bonds of interfacial water molecules, creating a local deformation coupled with the vibrational excitation. If the coupling is sufficiently strong, a new non-dissipative state associated with vibrational excitation and hydrogen bond distortion will propagate coherently. This mode of energy transfer is known as charge-transfer excitons. Charge transfer excitons come about from dipole-dipole and their interaction with quantum modes of vibration, i.e., phonon-polariton vibrations. These result in the coherent order of energy quanta induced by EM dipolar oscillations in and around the endogenous microstructure of neurons. Such charge-transfer excitons are commonly found in ionic crystal lattices, but they can also occur across polarized crystal lattices of water molecules where electrons and cavities occupy adjacent molecules [69]. The delocalized states in molecules are in sectors where enzymes reflect the boundary conditions limiting the molecular wavefunction and creating a partially holistic molecular environment with non-integrated information [6].

4. Phase transition order to chaos, thesaurus manifold

A living brain contains about 75% of water (a brackish aqueous liquid, liquor cerebrospinal), about 20% lipids and proteins and about 5% soluble organic matter, inorganic salts, and carbohydrates. All these are at the body temperature T_b =310 K; hence, the brain tissues and

their cells are constantly under thermal noise. This poses serious problems for processes associated with the brain's intellectual and cognitive functions since the disturbances will swallow them. This poses a problem for dynamic neuronal functioning concerning thermal scale at about $V_{\text{thermal}}=k_B T_b/e$ = 27 mV and is always large compared to the noise level across the membrane. We may adopt this quantity as a sort of limiting fluctuation level of actual brain tissues (e = 1.6×10^{-19} C is the electron charge). Thermal energy at body temperature is kT= 25meV. Anything below this value is insignificant functionally, and electrostatic attractions are eliminated by thermal vibrations and reduced to thermal noise. However, thermal energy cannot spontaneously disrupt weak bonds as the energy required to disrupt weak interactions between molecules is 40 meV.

The robust units with respect to this limit are atomic- ionic and molecular chemical elements, among which the hydrogen ion (proton) is most easy. Its lifetime in the water liquid is about δt = 2×10^{-13} s [70]. It is a lifetime when the hydrogen ion hops from one vacant hole to another. Let us evaluate the thermal action parameter at the body temperature T_b = 310 K for the free ion hopping:

$$\gamma = k_\beta T_b \cdot \delta t \sim 8.556 \times 10^{-34} \ \ \mathrm{J \cdot s} \qquad (1)$$

Compare this with the Planck constant h = 6.626×10^{-34} J·s. One more parameter can cause the inertial mass of the hydrogen ion in the water liquid:

$$m_s = \frac{k_\beta T_b}{c_s^2} \approx 1.88 \times 10^{-27} \ \ \mathrm{kg} \qquad (2).$$

Here c_s= 1508 m/s is the speed of the hydrogen ion in a saline water solution. Compare this with the proton mass m = 1.67×10^{-27} kg. The slight excess of the mass of m_s over the mass of a naked proton may explain that a proton moving in the water medium carries a cloud of negatively charged particles - electrons. The proton covered with a coat of negatively charged electrons makes it less mobile. For a more detailed investigation, see the renown work of [71] and [11]. The problem of the unusual behavior of anomalous conductances in water was reformulated in [9], see also [72], utilizing the formation of so-called coherent-dissipative structures, including the celebrated Grotthuss mechanism, see §5. The extended quantum chemistry and the Grotthuss mechanism showed excellent agreement with experimental data and predicted the anomalous decrease of H^+ mobility in H_2O/D_2O mixtures [9,73].

The above evaluations show good coincidences with the original physical parameters. It can mean that the hydrogen ions (protons) hopping in the brain fluid behave as correlated quantum objects. Typical of their motion is the Grotthuss mechanism [74,75]. According to this mechanism, presented above and in **Fig. 2(a)**, an effective proton movement involves rearranging the boundaries in a group of water molecules by reorienting a water molecule through approximately 1 radian (from 1 to 2 ps). The proton has very high mobility.

As the proton moves along the hexagonal water contour, it generates an EM alternating field perpendicular to this contour, shown in **Fig. 2(b)** by big arrows colored in yellow and cyan. On the other hand, the hexagonal lattice

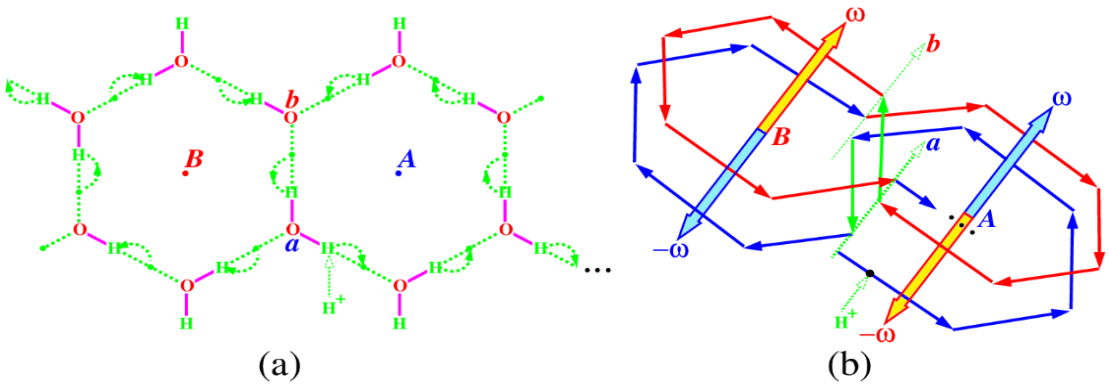

Fig. 2 *Grotthuss mechanism and appearance of a polariton at moving proton about the hexagonal water grid: (a) the Grotthuss mechanism shown on an example of two closed hexagonal oxygen contours. Here a hydrogen ion hops from a stationary oxygen atom to a neighboring one after it has rotated to the correct position between the two oxygen atoms; (b) a proton rotating along hexagonal oxygen contours and changing alternately the direction of bypassing of the contour induces EM wave (big arrows colored in yellow and cyan). The hexagonal oxygen grid thermal vibrations induce optical phonons. The optic phonons bound with the EM quanta represent the polaritons. Reproduced from [15].*

experiences thermal vibrations, reproducing optical phonons. These phonons, binding with EM waves generated by protons, create polaritons. Their energy consists partly of EM and partly of the energy of their excitations of the hexagonal lattice. Equations disclosing such a binding EM wave with optical phonons generated by thermal fluctuations of the matter lattice stem easily from the gravitomagnetic equations [76,77]:

$$\begin{aligned} &(\nabla\cdot\vec{\mathcal{B}}) = 0,\\ &[\nabla\times\vec{\mathcal{E}}] - \frac{\partial\vec{\mathcal{B}}}{c\partial t} = 0,\\ &(\nabla\cdot\vec{\mathcal{E}}) = 4\pi\wp,\\ &[\vec{\mathcal{B}}] + \frac{\partial\vec{\mathcal{E}}}{c\partial t} = -\frac{4\pi}{c}\vec{\mathfrak{J}}, \end{aligned} \tag{3}$$

Equations (3) are similar to Maxwell's equations. The variables $\wp$ and $\vec{\mathfrak{J}}$ represent the influence of external forces on the medium under consideration. The vector variables $\vec{\mathcal{E}}$and $\vec{\mathcal{B}}$ are those composed of a superposition of acoustic oscillations of a material medium and oscillations of EM field induced by motions of charged particles:

$$\vec{\mathcal{B}} = [\nabla\times\vec{p}], \tag{4}$$

$$\vec{\mathcal{E}} = \frac{\partial\vec{p}}{c\partial t} + (\nabla\cdot\varepsilon). \tag{5}$$

where the momentum $\vec{p}$ and the energy ε in the nonrelativistic limit looks as follows:

$$\vec{p} = c\rho_M\vec{v} - c\rho_e\vec{A}, \qquad \varepsilon = \rho_M\frac{v^2}{2} - \rho_e\Phi. \tag{6}$$

The first terms in these expressions relate to the material medium under consideration, and the second terms relate to the EM field through the EM potentials Φ and $\vec{A}$.

The first equations resulting from the gravitomagnetic ones are the wave equations loaded by internal and external sources of acoustic and EM oscillations [77] as follows from (3):

$$\begin{aligned} &\frac{\partial^2\vec{\mathcal{B}}}{c^2\partial t^2} - \nabla^2\vec{\mathcal{B}} = -\frac{4\pi}{c}[\nabla\times\vec{\mathfrak{J}}],\\ &\frac{\partial^2\vec{\mathcal{E}}}{c^2\partial t^2} - \nabla^2\vec{\mathcal{E}} = -4\pi\left(\nabla\wp + \frac{\partial\vec{\mathfrak{J}}}{C^2\partial t}\right). \end{aligned} \tag{7}$$

It should be borne in mind that these equations deal with the composed variables written out in (4)-(6). There are four wave equations, two for the material medium variables (ε, p_x, p_y, p_z) and two for the electromagnetic potentials (Φ, A_x, A_y, A_z). One pair of equations describes the propagation of optical phonons that arise in the material medium (excitation of the medium). The other pair describes the propagation of EM photons induced by moving charged particles (in our case, they are hydrogen ions (protons) exciting electromagnetic waves at hopping protons along the hexagonal ways in water, **Fig. 2(b)**).

The size of one water molecule (consisting of the positively charged nucleus of an oxygen atom attracting the electron cloud strongly to itself, exposing the hydrogen nuclei at the same time) is about 3 Å (angstrom), or about δr = 3×10^{-10} m [78]. A hydrogen ion (proton) jumping along a hexagonal water ring, **Fig. 3(a)**,

makes one jump for the time δt equal to about 2×10^{-13} s [70]. From here, we may evaluate the speed with which the hydrogen ion moves along the ring

$$v_H = \frac{\delta r}{\delta t} = 1500\ \mathrm{m/s}. \tag{8}$$

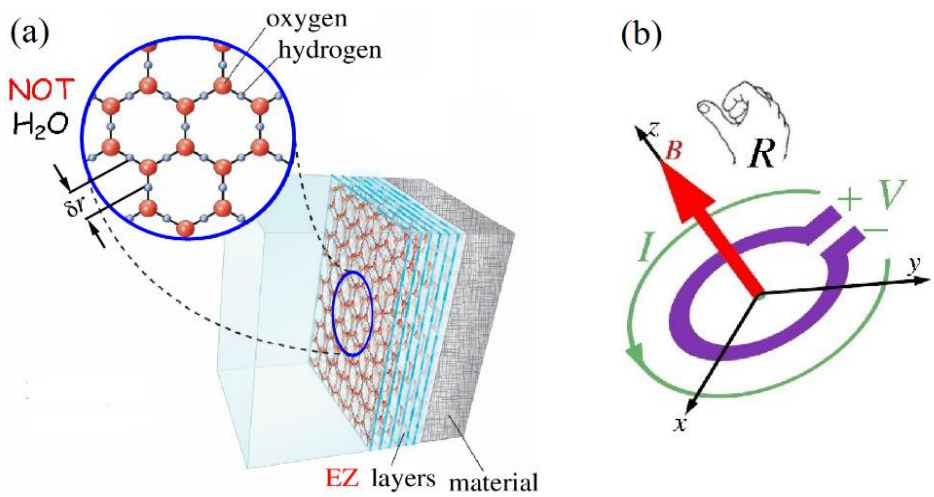

Fig. 3 *(a) From [79]. The hexagonal water lattice can work as an interferometric device acting as a receiving and transmitting antenna [15]. (b) Induction of the magnetic field according to the right-hand rule when the charge moves in a closed loop [76].*

First, this value is close to c_s = 1508 m/s taken from literary sources. With this value, we can immediately estimate the kinetic energy of the movement of the charged proton along the ring loop:

$$E_{kinetic} = \frac{m}{2} v_H^2 \approx 1.88 \times 10^{-21} \text{ J}. \quad (9)$$

Such a motion induces the magnetic field as drawn in **Figs. 2(b), and 3(b)**.

Before we pass the evaluations of thermal energy, we need to remember some laws from statistical physics [80]. In classical statistical physics, the proved so-called theorem on the uniform distribution of energy by degrees of freedom gives the following consequence. Suppose the system of molecules is in thermal equilibrium at temperature (T). In that case, the average kinetic energy is evenly distributed between all degrees of freedom. For each translational and rotational degree of freedom of the molecule, it is equal to $k_BT/2$. Let us first estimate the thermal energy at the triple point of water. This is the point at which water can exist simultaneously and in equilibrium in the form of three phases - solid, liquid and gaseous states. At this point, water molecules self-organize into a hexagonal cluster, typical of the formation of snowflakes. The triple point temperature is T =273.16 K. The thermal energy is as follows:

$$E_{thermal} = \frac{1}{2} k_B T \approx 1.88 \times 10^{-21} \text{ J}. \quad (10)$$

The amazing coincidence of the energies (9) and (10) says that at the triple point, the resonance conditions of the thermal and EM kinetic energies arise. This effect leads to the emergence of polaritons. By definition: polariton is a composite quasiparticle that occurs when EM photons interact with elementary excitations of the medium — optical phonons, excitons, plasmons, magnons, and so on. In our case, this interaction arises between a proton moving along the hexagonal ring, **Figs. 2(b), 3(b)**, and optical phonons induced by thermal oscillations in the triple point. Note that the energies (9) and (10) expressed in electron-voltage have values of about 11 mV, which is commensurate with the electric activity of neural cells. It means that the neuron's electrical activity is sensitive to the thermal fluctuations of water molecules.

Note that for the evaluation of the kinetic energy of the proton hopping in the water supported at the triple point, we have taken the naked proton mass. However, at a medium's higher temperatures, the proton is dressed in a coat of the accompanying electron cloud. It leads to weighting of the proton to some effective mass, which is slightly bigger than the naked mass. At body temperature, the ratio of the dressed mass to the naked one can be about 1.1 to 2.5. Due to such a mass shift, the resonance conditions of the thermal and EM kinetic energies can be stored at higher temperatures. Let us take the body temperature T_b =310 K, the dressed mass m^* about 1.9x10^{-27} kg. We get

$$E_{kinetic} = \frac{m^*}{2} v_H^2 \approx 2.138 \times 10^{-21} \text{ J}. \quad (11)$$

In turn, the thermal energy at the same temperature is

$$E_{thermal} = \frac{1}{2} k_B T_b \approx 2.139 \times 10^{-21} \text{ J}. \quad (12)$$

As one can see from a comparison of the quantities given in (11) and (12), we have resonance between the EM modes of the hopping protons and the optical and thermal fluctuations. Therefore, the probability of polaritons emerging is large enough. Let us also evaluate the characteristic frequencies of the oscillating modes. By dividing the energies (11) and (12) by the Planck constant, we find the natural frequencies relating to the EM field induced by the motion of protons along the closed loops and to the optical phonons induced by the thermal oscillations

$$\omega_{EM} = \frac{E_{kinetic}}{\hbar} \approx 2.028 \times 10^{13} \frac{1}{\text{s}},$$
$$\omega_{acoustic} = \frac{E_{thermal}}{\hbar} \approx 2.028 \times 10^{13} \frac{1}{\text{s}}. \quad (13)$$

The frequencies of about 20 THz are those of the infrared radiation at the temperature T= 310 K. It is instructive to remark that the polariton representing a resonant linking of thermal fluctuations of the hexagonal grating, **Fig. 3(a)**, with the EM waves emitted by this grating provides infrared radiation to the surrounding space.

The interaction of EM waves with the excitations of the medium, leading to their coupling, becomes especially strong when their frequencies and wave vectors coincide simultaneously (resonance). Such a coincidence can be achieved when the water comes to the fourth water state with the hexagonal ordering of water molecules [79,81]. It is a special state when the water excludes all foreign molecules away from its exclusion zone. This amazing state gives a possibility to support large coherent ensembles of the quasi-polaritons. Looking ahead, we can guess that such coherent ensembles may provide coupling of higher brain structures.

Transition to the states leading to polaritons in existence occurs with emerging the fourth water phase. It is a phase with a hexagonal ordering of water clusters. It excludes foreign molecules. For that reason, such a water state is pure, with the possibility of the appearance of quantum phenomena at room temperatures. The fourth water phase manifests quantum fluctuations related to Heisenberg's uncertainty principle. The proton dynamics under steady-

state conditions contrast with the normal water states where the thermal fluctuations suppress quantum effects.

A quantum critical point (QCP) is a point on the phase water diagram where a continuous phase transition occurs, **Fig. 4(a)**. The quantum critical point can be achieved by changing a voltage or a pressure applied to the water basin leading to a change in the system's physical state [79]. Second-order phase transitions are characterized by an increase in fluctuations on increasingly large length scales. Critical fluctuations at QCP, where the second-order transition occurs, are scale-invariant and extend to the entire system up to its boundaries.

One can see in **Fig. 4(a)** that QCP divides the phase diagram into two regions. The left part has ordered states, and the right part covers unordered states. As the control parameter tends to QCP, special conditions arise. Quantum fluctuations become long-lived (in some way, the time of life tends to infinity), and their correlation length also tends to infinity. It may mean that the fluctuations acquire a fractal-similar organization contributing to a high level of diversity.

Observe that the fluctuations in the region of order states are poor. In contrast, those in the region of disorder states look as the white d-correlated noise. In the region adjoined to the quantum critical point, the fractal-like fluctuations bear a character of the colored noise (the flicker noise $1/f^{\alpha}$, with the parameter α about 1).

As noted above, in the vicinity of QCP, an amazing phenomenon is in effect. Let us qualitatively consider the quantum phase transition on the example that has the following view:

$$S_Q = -\frac{1}{2}\ln(\rho). \qquad (14)$$

is the *quantum entropy* (dimensionless) [82]. Since the entropy is positive, we write the sign minus before ln (ρ), viz $S_Q = \begin{cases} +, & if\ 0 < \rho < 1, \\ -, & if\ \rho > 1. \end{cases}$

The term ln(ρ), accurate to the Boltzmann constant, k_B, represents the classical Boltzmann's entropy $S = k_B \cdot \ln(N)$, where $N = \rho \cdot \Delta V$ is the number of particles occupying the unit volume ΔV. The quantity ρ is the probability density that can range from zero but not larger than the number one. Note that the wave function is written in polar form

$$\Psi(\vec{r}, t) = \sqrt{\rho(\vec{r}, t)} \cdot \exp\{iS(\vec{r}, t)/\hbar\} \qquad (15)$$

contains the probability density distribution $\rho(\vec{r}, t)$ that appears in the multiplier as a square root from $\rho(\vec{r}, t)$. It determines the probability of detecting a particle near point $\vec{r}$ at time t. The action function $\overrightarrow{S(r, t)}$ in turn, determines the mobility of the particle near the same point $\vec{r}$ at the same time, t through the gradient of this function.

Let the control parameter of the entropy S be τ varying from zero to some maximum value, **Fig. 4(b)**. When it tends to zero, the entropy turns to zero. In this case, the diversity D disappears. Here we face with a strict order. When the control parameter reaches very high values, many symbols flitting around in a mess paralyze our perception. Here we face with chaos. In this region, the diversity D also tends to be zero because of tending to zero the correlation length. It is a monotonous mess. There is a transient region where the entropy possesses intermediate values, at which some variety in the permutations of symbols appears. This region adjoins the quantum critical point near which amazing fractal-like fluctuations arise, **Fig. 4(a)**.

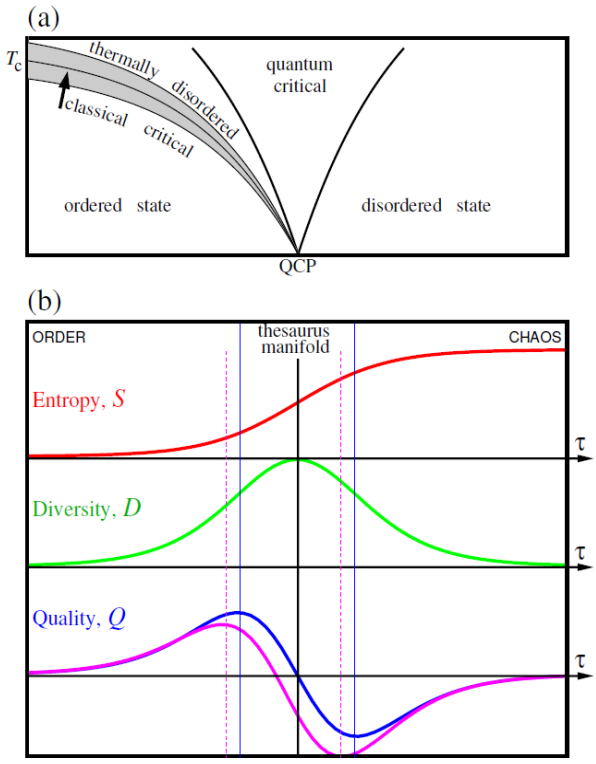

Fig. 4. *Phase transition at crossing the quantum critical point (QCP): (a) Generic phase diagram in the vicinity of a continuous quantum phase transition. The horizontal axis represents the control parameter τ (pressure, for example) used to tune the system through the QPT, and the vertical axis is the temperature T [83]. T_c is the critical temperature of the Landau-Ginsburg superconductivity. (b) Quantum entropy S (red), (8). Diversity D (green), (10). Quality Q (blue), (11), a curve colored in pink, draws the quantum potential, (12). On the left, there is a strict order. On the right, there is chaos. In the middle, there is a transition from order to chaos. Here fluctuations demonstrate a fractal-like nature. Within this region, the thesaurus manifold is located.*

If the entropy (8), $S = -\ln(\rho)/2$, as a function of the control parameter τ varies as a sigmoid function, see the blue curve

in Fig. 4(b), then the diversity, *D*, calculated by the formula

$$D(\tau) = \frac{dS(\tau)}{d\tau} = -\frac{1}{2\rho}\frac{d\rho}{d\tau} \quad (16)$$

It looks like a bell. See the green curve in **Fig. 4(b)**.
Let us now calculate the second derivative from *S* by τ. We will get

$$Q(\tau) = \frac{d^2S(\tau)}{d\,\tau^2} = \frac{\left(\frac{d\rho}{d\tau}\right)^2}{2\rho^2} - \frac{\frac{d^2\rho}{d\tau^2}}{2\rho}. \quad (17)$$

This curve is shown in **Fig. 4(b)** in blue. It characterizes the fractal-like fluctuating patterns' quality by extracting them using their derivative's negative slope. Thin blue vertical lines in this figure allocate the thesaurus manifold.

4.1 Definition of thesaurus

A set of optimal symbols for communications between different beings belonging to one species (such as phonemes are – the minimum semantic units of a language [84]. The most effective phonemes for communications are within the thesaurus manifold. By definition, a thesaurus or synonym dictionary is a reference work for finding synonyms and sometimes antonyms of words. All these thesauri are in a range where the entropy undergoes significant variations, as shown conditionally in **Fig. 4(b)**.

It is instructive to note here that the pink curve shifted to the left has the following mathematical representation:

$$Q(\tau) = \frac{\left(\frac{d\rho}{d\tau}\right)^2}{4\rho^2} - \frac{\frac{d^2\rho}{d\tau^2}}{2\rho}. \quad (18)$$

Differences between these two curves are in the denominators of the first term. The first blue curve has in the denominator the number 2. While the second magenta curve has in the same place the number 4. Observe that this curve can represent the quantum potential if the control parameter, τ, will relate to the space coordinate $\vec{r}$.In this case, the above equation accurate to the factor $\hbar^2/2m$, will be as follows [85]:

$$Q(\vec{r}) = \frac{\hbar^2}{2m}\left(\frac{(\nabla\rho)^2}{4\rho^2} - \frac{\nabla^2\rho}{2\rho}\right). \quad (19)$$

Let us end this section with the thought of David Bohm about the quantum potential and its link with the mind. [86] did suggest that active information links the mind and the brain but never explicitly. He also suggested that mind-like behavior exists through the "*dance of electrons*" and its nonconscious 'quantum force' causing actual physical feelings, nonintegrated information transporting *inherent meaning* and relations between them. The Bohmian '*dance of electrons*' bears on active information that physically reflects on the internal energy directly associated with the quantum potential energy [87]. Accordingly, active information redistributes the internal energy shared between the kinetic and potential parts [16]. These internal energies distinguish the extended character of quantum systems from the point-like integrity of individual classical systems from which they are absent.

What can be the path from quantum critical fluctuations to quantum-thermal fluctuations? This question requires separate consideration.

5. Grotthuss-like structures underlying quantum-thermal fluctuations

The thermodynamic picture makes quantum effects commensurate to thermal effects [36]. See the **Appendix** for an alternative theoretical approach based on quantum chemistry where the Grotthuss mechanism is a realistic example of a representation of the density matrix quantum transition, followed by the next step, building a higher order propagator/generator based on the Grotthuss-like structures, all tied to the temperature and the associated time scales.

6. Stabilization of quasi-polaritons

The destabilization specifically causes oscillating charges in biomolecules resulting in a large number of energy quanta condensing into a single state, Fröhlich-style condensate, which can actuate a vibronic mode that induces a physical and non-thermal interaction between molecules [88]. It is postulated that quasi-polaritons create self-organization due to *condensation-like induced stability* [89]. The Fröhlich-style *condensation* strongly couples photons with non-inert matter, which is why the system self-organizes into a stable state. Numerous studies point to 'dipolar order' at the macroscopic level via hydrogen bonds (e.g., [66,67,90]). At a macroscopic level, the processes of protein folding as conformational transitions are coherent excitations resulting from the structural coherence of hydrophobic molecular dipoles in a common voltage gradient (under quasi-electrostatic conditions) termed Fröhlich-style *condensation-like excitations* [89,91,92]. Coherence requires molecular quantum mechanics, but only exceptional quantum states avoid decoherence at room temperature. The Fröhlich-style condensate is a state that persists at room temperature if induced by the quasi-polariton formation in submicron neuronal branchlets [93].

Wu & Austin [94] proposed a model to describe the interaction of the quantized EM field with dipolar molecules to yield a coherent Fröhlich-style condensate of energy quanta of excited collective polar modes of vibration (see also [95,96]). The Fröhlich-style condensate would be unstable in the brain's noisy, warm and wet medium. The quasi-polariton is stable at room temperature and is induced by the confined (endogenous) EM field.

The quasi-polariton model requires that the quantum state of the brain has a property called ***macroscopic quantum***

coherence, which needs to be maintained for around a few milliseconds. In the absence of polaritons, the decay of the vibration at under 10^{-13} s [97] is much too quickly before they can be stabilized by Bose-Einstein condensation, but not so by replacing the phonons (vibrations) by phonon-polaritons. Without coherent ordering of water dipolar molecules, molecular dipoles in neurons possess a decoherence timescale under 10^{-13}s [97]. Craddock and colleagues [98] claim that quantum states are sufficiently insulated in microtubules to prevent thermal decoherence based on negligible nuclear spin energy. However, this is not likely to happen in addition, and the situation should occur not just in the microtubules but throughout the non-polar regions in cells [99,100].

Can the quasi-polaritons be protected from EM influences by coherent ordering in the crystal lattices of water molecules? In this way, one could model the quasi-polaritons to be protected from outside perturbations, thermal noise, EM fields etc., by the coherent ordering of the amorphous Grotthuss water wires confined to hydrophobic cylindrical channels in the cerebral water medium [101]. The interactions that can occur in the crystal lattices of interfacial water identify the brain to exhibit *quantum-like* behavior at the molecular level [102]. The crystal lattice structure of interfacial water keeps the entropy low, and the characteristic stability of *quantum-like* coherent states ensues, yet at non-thermo-regulated biological conditions [103]. Phonon-polaritons are EM waves coupled to lattice vibrational modes. Still, when generated specifically by protons, they are referred to as phonon-coupled *quasi-particles*, i.e., providing a coupling with vibrational motions. They carry away the quasi-free electronic kinetic energy[1], giving rise to quasi-polaritons upon reaching the electro-ionic brain (**Fig. 5**).

The major forces between dipole molecules are of an EM nature. Such forces can result in EM dipolar oscillations, and as a consequence, all catalyzed reactions result from conformational changes via mechanisms similar to protein folding. Nevertheless, bonding preferences between amino acids do not play a significant role in coding the protein. Metabolic energy sources play a fundamental role in EM couplings to quantized polarization waves between dipolar molecules sensitive to endogenous EM fields. In particular, releasing photons by either mitochondrial activity or as its by-product resulting from free radical reactions can be of major significance in this connection [104,105,106]. These EM states may induce polaritons through strong coupling of photon-phonon interaction. The quantized polarization waves originate from dipole-dipole and dipolar molecular interactions in the crystal-like hexagonal lattice structure of interfacial water [81] (i.e., degenerating into vibrations with conformational states and conformational transitions). The ensuing traveling strongly coupled conformational wave [107,108] is sensitive to the endogenous EM field at the molecular level, resulting in phonon-polariton vibrations.

Once these vibrations manifest as waves, consisting of the quasiparticles resulting from the coupling between phonons and the EM field, with a kinetic energy 10^{-5} times smaller than thermal noise in neurons [93], to survive to resist thermal noise, bare polaritons attract the additional mass of interfacial water molecules and building their kinetic energy by propagation in a crystal lattice of phonons, where the quasi-polaritons become the result of ion-dipole interactions. It should be emphasized that there is no electro-diffusion of ions or ionic variability since the ion-dipolar interaction involves a fixed ion attaching to the bare polaritons, becoming quasi-polaritons.

The significantly hypothetical increases in the lifetime of bare polaritons in the crystal lattices above, with periods on the picosecond timescale, will give them a far from quasi-equilibrium thermodynamics situation, constantly being updated from the energy transport in discrete crystal lattices to the continuous charge transfer processes in molecules by attachment to the ions, governed by nanosecond timescales and the appearing dipolar oscillations in the microstructure [109]. Interfacial water enables causation to be carried in neuronal branchlets at relevant frequencies of the coherent domains (approximately 0.1μm in diameter that includes millions of dipolar molecules), which is fertile ground for energy transfer [110]. The characteristic frequency of the coherent domains is based on Szent-Gyorgyi's [111] concept of frequency changes when energy is stored in a coherent domain. If other dipolar molecules oscillate at the boundary with the same frequency, they will become part of the coherent domain. The hypothesis, in this way, amounts to harnessing stored energy of the coherent domain and transporting intrinsic quantum fluctuations across the brain as energy transfer. This might provide a viable hypothesis, equivalent to the Fröhlich effect, i.e., that the energy provided may not be completely thermalized but redistributed towards lower frequency modes of vibration.

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[1]Quasi-free electrons interact in the crystal lattices with phonon-polaritons that carry away their kinetic energy.

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The endogenous EM field at the molecular level is not a self-propagating 'conscious' exogenous EM field, which governs the emission and absorption of energy quanta prone to *magnetic instabilities*. To understand how *magnetic instabilities* arise in the brain, we must first pinpoint that quasi-electrostatic fields are time-varying. However, the electric and magnetic fields may still be decoupled, even though there is a time-dependent variation of the fields, which means that a time-varying electric field will give rise to a time-varying magnetic field and *vice versa*. Magnetic instabilities arise from magnetic gradient force (cf. [112,113]) or a changing magnetic vector potential (cf. [44,114,115]), potentially resulting in energy transfer to stabilize quasi-polaritons in very thin, distally isolated branchlets.

7. Phonon-polariton vibrations as a conduit for protonic currents at the cellular scale

Interfacial water crystal lattice structure acts as a transfer medium for endogenous EM waves to dipolar molecules resulting in conformational waves (=quantized polarization waves in interfacial water crystal lattices). Conformational changes occurring on the order of nanoseconds and more are triggered by charge redistribution, which may be caused by EM dipole oscillation within hydrophobic regions of dipolar molecules [89]. The flow of charged particles like protons, i.e., hydrogen ions, across the mitochondrial membrane gives the metabolic enzymes energy to produce ATP through *chemiosmosis*. Such external feeding of energy

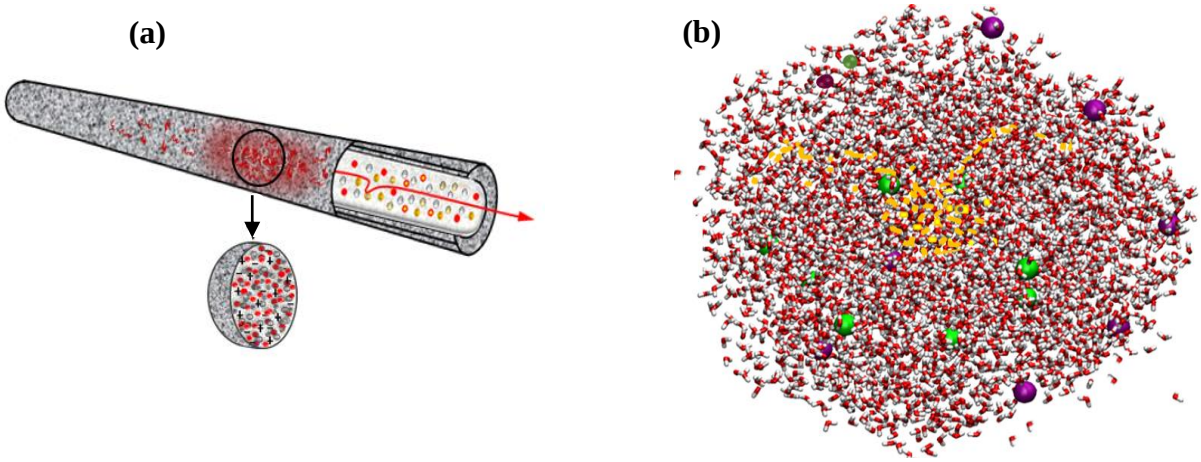

Fig 5. (a) *Schematic diagram illustrating a terminal cortical interneuron branchlet containing dipolar molecules in an endogenous EM field where molecular dipoles (not to size) are arranged in an orderly fashion surrounded by the charged milieu of interfacial water. The quantized polarization-induced behavior of dipolar molecules leads to a polaritonic wave (red arrow) arising in the microstructure of the neuronal branchlet of uniform diameter of under 100 nm and about 0.7μm in length. The polariton originates in the EM brain from constituents of quasi-polaritons propagating at speed (v) much slower than the velocity of light (c) (i.e., v << c). The size of the bare polariton as a quasi-particle wave is at most 25nm [68]. Still, the quasi-polariton is much larger within the limits of coherent domains of interfacial water (100nm) and the approximate size of very thin neuronal branchlets. The mid-region shows a greater propensity of dipolar molecules, as shown in the inset for illustrative purposes resulting in movement of charge redistribution.* ***(b)*** *Schematic diagram illustrates the fluxes of photons relating to quasiparticles such as polaritons propagating in the van der Waals heterostructures of water lattice molecules and ions, thus acquiring mass so that they are unable to propagate but appear as coherent energy of water molecules or quasi-polaritons that eventually become phonon-polariton vibrations upon interactions with phonons arising from molecular vibrations and quantum thermalization.*

through the ATP molecule reaction may trigger the gives the metabolic enzymes energy formation of macroscale quantum-like solitons in interfacial water [62, 116] when coupled with photons [106] to generate phonon transport through a dynamically ordered region of water surrounding a dipolar molecule up to the coherence length (CL) < 50 microns, which would cover most of the cell's interior [64].

The 100 nm limit of interfacial water coherence domains at ordinary temperature and pressure [117,118] indicates that protons can behave like quantum objects, subject to long-range order, in these confined spaces. Moreover, they can be coupled to EM signals carrying quasi-polaritons through membrane proteins, which are present at a higher density in the mammalian cortex [119,120]. Whether energy transfer describing quasi-polaritons between interneuron branchlets in the cortex in the brain is feasible remains yet to be experimentally proven. Theoretical work in this direction has been proposed by Hameroff [56]. Amino acids with resonant side-chain structure (conjugate bonds), including *phenylalanine, tryptophan, and tyrosine* (with aromatic ring), are the molecular basis by which delocalized electrons are to be thermally excited and vibrationally correlated. The molecular realm of quantum energy processing involves energy transfer within protein pathways between different cortical regions and energy transduction at a particular protein that constrains energy and produces intrinsic information.

Enzymes (amino acids) 'provide' under steady-state and changeable boundary conditions, constraining the reorganization of free energy and corresponding entropy flows, creating intrinsic information. The constraining boundary conditions result in the negentropic gain that balances the entropy production, resulting in delayed entropy, enabling its eventual elimination after steady-state conditions in the environment as a consequence of the steady-state condition [121]. As a macroscopic description of quantum effects in aromatic residues of amino acids, the quantum cooperative mechanism of enzymatic activity acts as the biological substrate for transduction between quantum and classical domains [122].

Random thermal motion in a wet environment would promote decoherence, but under Fröhlich's [91,123] proposal, systems far from equilibrium with energy provided by phonon vibrations were hypothesized to allow thermalized effects to promote large-scale quantum coherence of proteins. These sizes require the corresponding frequencies of phonon vibrations from 100 MHz to 1 GHz, while EM waves would have the corresponding frequencies in the 1 to 10 THz range [41-124].

Without the coherent-dissipative mechanism, see, e.g., [9], these polaritons cannot form coherent condensates at room temperatures. However, under steady-state conditions, Fröhlich-type ordering might survive with their energy pumped/activated) through *chemiosmosis*. The presence of quasi-phonons, which consist of modulated EM field energy, is supplied through proton conductance. It is suggested that protonic conduction transmits intrinsic information as thermo-qubits and physical feelings. For a definition of physical feelings, see [6] in a complex water medium.

The quasi-protons consist of a layer of negative charge torque that transmits energy and signals by ultra-rapid communication based on combining the classical *Grothuss mechanism* with the coherent-dissipative quantum formulation where the pH-directed assembly transmits, under steady-state conditions, quantum-thermal signals by off-diagonal long-range correlative communication, ODLCI (see **Appendix),** where quasi-protons attach to one end of the *Grotthuss hydrogen bond network* and leave at another end of the structure with hydrogen bonds maintaining the coupling of atoms under thermal fluctuations. Some hydrogens bonds break, but others arise on average, and equilibrium of different cluster sizes is maintained.

On the molecular scale, two separate mechanisms operate in the fluid environment of the brain [15]: (i) intermolecular communication based on protonic currents (*Grotthuss mechanism*) and (ii) quasiparticle formation. At the cellular scale, quasi-polaritons and quasi-phonons from which protonic currents result (i.e., proton motion tied to hydrogen bonds) have the unique property of dipolar order, which resists degeneration by thermal noise, and which gives rise to such vibrations. Dipole moment coupling to conformational states in interfacial water dipolar molecules and molecular conformational transitions was first postulated by Fröhlich [89]. Interfacial water contains a narrow zone of protons, as positively charged hydrogen ions, which can move very rapidly in water hopping from one water molecule to the next. The principle of protonic conduction in water involving the *Grotthuss mechanism* has recently been simulated, criticizing the oversimplified conventional picture, advocating a deeper understanding of water's more complex supra-molecular structure [125], seemingly providing additional arguments for the current set of formulations. Proton conduction is supported by the interaction with acoustic phonon-polaritons, which in the presence of an EM field at the molecular level and provided the temperature is low enough, can lead to superfluid like-dynamics, which is the capacity of quantum fluid to move without dissipation [126].

At the cellular scale, one can interpret the EM field as a mode of nonsynaptic communication in the nervous system [127]. However, this oversimplifies the subcellular scale, where the EM waves and energy waves manifest the underlying signaling modes. The quasi-proton consisting of a layer of negative charge torque transmits energy-entropy through signals by quantum-thermal communication based on the *Grothuss-like mechanism*. The model is quite attractive in that the quasi-protons 'tunnel' from one water molecule to the next, or rather from one end of the transport structure to the other, with the hydrogen bonds maintaining the coupling of the ingoing atoms under thermal fluctuations. Some hydrogens bonds break, but others arise on average, and equilibrium of different cluster sizes is maintained [9,13].

8. Negentropic entanglement of multiscale 'bits' of information

Schrödinger [28] introduced the idea of an "aperiodic crystal" to describe how the storage of genetic information might work in a living organism. A second theoretical notion was the concept of "negentropy". This book became very influential, as witnessed by several readers and many aspiring future scientists. It is to be noted that the book appeared almost 10 years before the celebrated discovery of the physical basis of heredity by Watson & Crick [128]. Schrödinger explains that living organisms evade the decay to thermodynamical equilibrium by homeostatically maintaining negative entropy in an open system. Modern approaches to non-equilibrium thermodynamics, e.g., [17], have rephrased the problem regarding entropy production and negentropic gain during steady-state conditions. Based on the philosophical framework of panexperiential materialism [14], one can attach the principles above to work out the physical basis of sentience in living organisms.

The origin of intrinsic information is quantum-thermal fluctuations leading to thermo-qubits perturbing the negentropic action of proton conduction in phase space during the steady-state situation and negentropically derived quantum potential energy. As energy is transduced, other bits of information arise. The quantum objects, taking part in the process of transferring bit units in biological systems, such as in a complex water medium, are open system material degrees of freedom, communicating via thermo-qubits and physical feelings, the latter unconscious raw microfeels [129]. The open quantum system is subject to the Liouville-Bloch equation for its evolution. A somewhat different approach, particularly in connection with low-temperature phenomena, entangled photons, quantum computation etc., provides a general guide to quantum state diffusion [58], taking the reader from Brownian motion to systems continuously interacting with its environment and preparing the perspective of the de-Broglie -Bohm theory [130].

However, the strategy combines the two in a hydrodynamic equation with temperature-dependent quantum potentials, modeling protonic excess conductivity rates to transmit intrinsic information in aqueous solutions via the thermo-qubit syntax, promoting unconscious physical feelings. Indeed, the consciousness process originates in an integrated admixture of quantum-thermal fluctuations preparing the thermo-qubit syntax creating causal-like behavior by information-based negentropic action. Given the multiscale nature of intrinsic information, the phonon-polariton vibrational characteristics in the transport current are considered to be the bits of information transmitted across the brain's cerebral hemispheres by the quantum-extended *Grotthuss mechanism* (see [9,13, 15]).

The multiscale 'bits' of information juxtapose several mechanisms at the quantum/classical regime boundary. The negentropic entanglement of multiple 'bits' of information results through the balancing act between entropy production and entropy lowering producing a 'negentropic force'. The associated negentropic entanglement appears by recognizing the *long-range phase coherency* associated with the protonic currents and their quantum-thermal, intrinsic order. This causes a different quantum entanglement process to subsist irreducibly in the brain's environment between evanescent meanings—a variable formation process occurring when *negentropic gain* balances entropy production and producing, e.g., Fisher's information (dimensionless) from constrained energy-entropy release. The negentropic action in phase-space for quasi-proton conduction aids in negentropic entanglement through the negentropically derived quantum potential (Q_{sq}) expressed in Newton [15]:

$$\frac{\partial \nabla S^*}{\partial t} + \frac{1}{2m}\nabla(\nabla S^* - e\mathbf{A})^2 + e\nabla\phi + \nu(t)m\frac{\partial \nabla \ln(p)}{\partial t} + \nabla(Q_{sq} + U) = 0 \tag{20}$$

Here S* is the 'spread' function, carries dimensions of [energy] [time], t is time, m is the effective mass of protons, ϕ is the electric potential, **A** is the magnetic vector potential, ν is the viscosity of the water medium, ρ is the current density of protons, e is the electron charge, ∇^2 is the Laplacian, U is the classical potential energy, and the negentropically derived quantum potential is

$$Q_{sq} = -\frac{\gamma^2}{2m}[\nabla S_Q]^2 + \frac{\gamma^2}{2m}\nabla^2 S_Q \tag{21}$$

where γ is the action parameter (1). Equation (21) describes the spatial-temporal distribution of the ensemble

assumed to generate a modification and, thus, a degree of 'order' of the appearing information entropy characterized by (14). The first term on the RHS of (21) is viewed as the 'corrector' of the kinetic energy term, and the second term on the RHS influences the classical potential energy term U.

To a first approximation, the dissipative Schrödinger-like equation (see[6]), we assume that the dissipation parameter (see below) is independent of space position in the brain than from the neural Hamilton-Jacobi equation, the kinetic energy becomes $\frac{1}{2\mathrm{m}}(\nabla S^*)^2 - \frac{\gamma^2}{2\mathrm{m}}[\nabla \mathrm{S_Q}]^2$ and the classical potential energy becomes $\mathrm{U} + \frac{\gamma^2}{2\mathrm{m}}\nabla^2 \mathrm{S_Q} = 0$. This implies that the kinetic energy of the ensemble of proton distributions via phase differences contains a negentropic term $\frac{\gamma^2}{2\mathrm{m}}[\nabla \mathrm{S_Q}]^2$ which 'informs' or communicates inherent 'meaning' related to gain in intrinsic information.

Internal energies reflect nonlocal correlations of phase differences, resulting in energy exchange from potential to kinetic energy. The free energy of de Broglie's hidden thermodynamics provides constraints for *negentropic gains* in the steady-state situation, leading to inherent *'meaning'*. The *negentropic gain* is $\langle Q_{sq}\rangle - S_Q > 0$ where $\langle Q_{sq}\rangle$ is the expectation value (dimensionless) of the quantum potential has a secondary role in conveying so-called *inherent* 'meaning'. The latter can never be definite, for the 'meaning' must be continuously qualified. The reference to 'meaning' alludes to semantics as conveyors of 'meaning', and the word 'informs' alludes to concealed motion on account of the negentropic term $\frac{\gamma^2}{2m}\nabla^2 S_Q$ canceling the classical potential energy $U = -\frac{\gamma^2}{2m}\nabla^2 S_Q$. The negentropically derived quantum potential energy ($\mathrm{Q_{sq}}$) represents a casual effect through quantum-thermal fluctuations.

We define the negentropically-derived quantum potential (Q_{sq}) to be quantum-thermal internal energy, representing the mesoscopically aggregated effect of the microscopic random quantum-thermal fluctuations. The origin of quantum-thermal fluctuations can be thought of as the movement of quantum potential energy rather than kinetic energy due to the large fluctuations that emerge from the constant jiggling of neighboring atoms/molecules in a warm brain environment. The nonthermal motion of electronic-conformational interactions allows for the exchange between quantum potential energy and kinetic energy.

The thermal and quantum fluctuations exert com-mensurable competing effects and become '*mixed*' as both thermal and quantum fluctuations. This can be observed with the temperature dependence of the quantum potential. We note that $\nabla \mathrm{E}/\nabla \mathrm{S} = T$ (*Tsekov, personal communication*), where S is the entropy in units of [energy]/Kelvin and $E = -\frac{\partial(S^* + \gamma\beta_i)}{\partial t}$ is the total energy where $\beta = \beta r + i\beta i$ is the dissipation parameter (dimensionless) [6,131]. It is possible to find the dissipative quantum potential energy as a function of *T*, and since the *Boltzmann-Gibbs thermal entropy* is dimensionless, the connection is established by multiplication by the Boltzmann constant k_B. First, we note that $\nabla \mathrm{S_Q} = (-\frac{1}{2k_B})\nabla S$ and from (21), we have

$$Q_{sq} = -\frac{\gamma^2}{8\mathrm{m}T^2k_B^2}[\nabla(\frac{\partial S^*}{\partial t})]^2 - \frac{\gamma^2}{4\mathrm{m}\mathrm{T}k_B}\nabla^2(\frac{\partial S^*}{\partial t}) \qquad (22)$$

where T is the temperature in Kelvin, note that the temperature-dependent quantum potential depends on the temporal derivate of the 'spread' action function. In quantum potential chemistry, the quantum potential energy depends on both the 'spread' function and the temperature, so it is a multiscale concept from micro to macro.

Does the macroscopic quantum potential contribute to holonomic effects? This can happen when the action becomes the phase. In other words, the action function of an ensemble of proton distributions in phase space is converted into the "spread function" or a distributed process as proposed in holonomic brain theory [21].

The macroscopic quantum potential dependence on temperature and the rate of change of phase difference (i.e., the temporal derivative of the spread function) as frequency/fluctuations (f) gives the following definition of quantum-thermal fluctuations:

$$Q_{sq} = -\frac{\gamma^2}{8\mathrm{m}T^2k_B^2}(\nabla f)^2 - \frac{\gamma^2}{4\mathrm{m}\mathrm{T}k_B}\nabla^2 f \qquad (23)$$

where T is the temperature in Kelvin, k_B is Boltzmann's constant in units of [energy]/Kelvin, f is in units of [energy], γ is a spread action function parameter in units of [energy][time], t is time [time], m is the effective mass of protons in units of [mass], ∇ is the gradient in units of $[\text{length}]^{-1}$, and ∇^2 is the Laplacian in units of $[\text{length}]^{-2}$.

The *negentropic force* ($-\nabla Q_{sq}$) is obtained from such quantum-thermal fluctuations. An interesting observation is that the dynamics of the macroscopic quantum potential are dependent on continuous change in the quantum-thermal fluctuations. When temperature increases, the quantum potential energy decreases. The temperature-dependent quantum potential at the mesoscopic level is where energy-entropy dissipation occurs, defining what we know to be "thermoquantual information" [14].

The real component for Q_{sq} is temporally positive and negative in amplitude. This signifies how the internal Thermo-quantum internal energy is a somewhat strange

concept. However, under the de Broglie guiding equation, the microscopic thermal motion or fluctuation is represented by the imaginary part of the thermo-quantum internal energy. This is an analog of Boltzmann-Gibbs classical entropy to the realm of quantum hydrodynamics, but a perfect analogy does not exist. This is not the von Neumann entropy in units of the Boltzmann constant. Still, it is a density of the complex entropy concept based on Fisher (real) and Shannon (imaginary components) [132]. It should be mentioned this randomness originates from quantum thermal fusion. The quantum thermal fusion that imparts thermo-qubits for communication is not a dual aspect – it is an irreducible correlation process beginning at the fundamental microscopic level and does not separate (classical and non-classical) information in the real- and imaginary parts of the complex entropy [132]. In other words, Fisher's information represents the smear of possible experiences in the brain as an approximation to the Shannon formalism [14,133]. This is characterized by S_Q which is positive and negative, in which negative S_Q denotes information [134], that is, information (theoretic) entropy (a measure of the uncertainty of data in an 'information channel') via *Brillouin's negentropy principle of information* [26,27], essentially equivalent to thermal entropy [37,135]. Note: Dimensionality in the transduction process is not conserved.

We show how intrinsic information arises from the change of physical states of the composition of panexperiential matter in the brain. Shannon declared the unit of information as a 'bit'. Shannon's Information has no definitive "*states of physical properties*" since its coupling with the chemical entropy concept refers to the possible amount of information that can be transferred through a particular channel and thus yields no knowledge about definitive "states of physical properties" as the intrinsic information contains. The intrinsic information encoded in the brain's quasiparticles appears under the constraint of entropy production generated by a physical agent. Information in the sense of changing transitions of physical states or the change of states in the materialistic brain. This should not be conflated with the conventional notions of objective brain states. The rate of change of brain states infers a contiguous scale from objectivity to subjectivity. Therefore, the notion of 'qubit' as a basic unit of quantum information or 'thermo-qubit' as produced by quantum-thermal fluctuations or further the diffusion particulars of a quantum state or the quantum potential energy-carrying temperature dependence is an example of fundamental quantum-thermal interactions from the quantum scale to classicality.

Intrinsic information is active and has an associative action. The passage of intrinsic information, the Q_{sq} that gives form to partially holistic molecules, is through *negentropic force* $f_{S_Q} = -\nabla Q_{sq}$. A zero negentropic force implies phase incoherency. If the quantum entropy becomes negative, it signifies that long-range phase coherence will increase quantum potentiality and function as an "*integrator*" of non-integrated intrinsic information through *negentropic force* underlying nonlocal holonomy in partially holistic molecules. Note that the energy is transferred in discrete jumps or 'quanta' and that these jumps are resonance structures breaking away from the continuum, including energy and time scales, in a more exact formulation. Partially holistic molecules are sectors of molecules that are influenced by nonlocal holonomy that carry 'meaning' through negentropic force. The latter is the flow of Q_{sq} through a repulsive force due to the negentropically derived quantum potential.

Intrinsic information is fundamentally a carrier of ambiguous meanings. The "quanta of information" is minimum uncertainty and a measure of causal capacity syntax/language, counterbalancing the related entropy production and instigating a measure of causal capacity. It is a bridge to causality (conscious experience). The semantic aspects of information are ignored in a Turing computation. Hence the *act of observation* can be measured by entropy deficiency or information distance between Fisher and Shannon. However, this may not be easy to carry out since the two concepts provide alternative measures of information, one concentrating on the physical entropy concept, while the other concerns the additional knowledge due to negentropic gain, providing deviation from the standard distribution.

Nevertheless, the Fisher- and the negentropic action from a Shannon investigation should give comparative information measures that reflect the pattern's overall 'order' or 'sharpness' of transporting the information. We have called such distributed process to reflect upon "quanta of information" as physical feelings, and consciousness is the actualization of physical feelings by the *act of observation***.** This happens when consciousness begins, which includes Fisher's information as a smear of possible experiences related to negentropic gain, becoming related to Shannon's information in a steady-state situation.

As already stressed, Shannon's information reflects uncertainty or '*disorder*', while Fisher provides a measure of its narrowness or 'order'. Shannon information probes an average measure, cf. the concept of entropy, over a large domain. In contrast, Fisher's information provides a local measure of the distribution or sharpness of inhomogeneity, cf. the deviation from a given distribution. Distributed processes like Shannon information are non-

structural; localized processes like Fisher information are structured and comprise information structure in the brain. The information structure is found in the spectral domain as a sinusoid (later extended to open-state dynamics), which rapidly finds correlations by harmonizing one pattern with another. In the brain, interference patterns may result in scales of matching patterns. Intrinsic information performs under steady-state conditions, i.e., it does not generate changes in total entropy. Negentropy is produced at the expense of producing entropy transferring intrinsic nonintegrated information. Lowering entropy in the biological system, such as the brain, becomes a fundamental feature of the open system, while the heat is excessed elsewhere. We have associated negentropy with the Fisher information as the difference between equilibrium and a given nonequilibrium organization.

9. Conclusions

The holonomic brain theory requires a new way to characterize distributive processes in the brain. The proof comes from an inter-cerebral superfast, extemporaneous information pathway that binds the complex action of neurons in a collective presentation with different brain regions [136,137]. Moreover, protons are convenient quantum objects for transferring bit units in a complex water medium like the brain. The phonon-polariton interaction in such a medium adds informational complexity. As for proteins, they are exclusionary involved. Protein-protein interactions involving complex protein interactions are essential for the communication patterns starting already at a superfluid-like highway enabling the consciousness process to penetrate actual brain regions due to a different regulated gene set as opposed to single region-specific genes. There are no genes expressing consciousness (cf. [138]). While unconscious complex correlative long-range order begins at complex molecular complexes, consciousness shows brain rhythms in slow frequencies with packets of fast frequency embedded in them. This bispectrum is key to understanding how protein pathways in the cerebral cortices are connected in a single network of thousands of proteins to neural activity and move up the scale to perception and cognition, including memory, which often designates the ultimate bottom-up end of the consciousness process.

The notions of macro-causal emergence and micro-causal exclusion of intrinsic information in integrated information theory fix the spatiotemporal scale of consciousness [139]. We suggest that the quantum biophysical basis of consciousness rests in multiscale 'bits' of information across scales by redefining the holonomic formalism with Madelung's quantum hydrodynamic [140] descriptions of constructive thermal quantum-chemical fluctuations in the EM brain as the chemical signals assemble phase coherence in the charge redistribution of the perturbed dipolar oscillations. *The polarization waves* that emerge from interfacial water molecules' functional capabilities are controlled by quantum hydrodynamics involving delocalized electron densities and hydrogen bonds in an electromagnetic field, in which ordered water formations within appearing microstructures are coupled to polarization waves (collective excitations) and perturbed EM stimulated phonon-photon vibrational patterns. The *polariton waves* affect the charge redistribution momentum in interfacial water and serve as a conduit for transferring energy to the electro-ionic brain, resulting in protonic conduction of thermo-qubits through long-range correlative communication in the cerebral hemispheres.

Appendix

Biomolecular systems, in contact with their environments, necessitate a collective integration of quantum-thermal fluctuations/correlations characterized by the thermal time scale at temperature T, given by $t_{\mathrm{corr}} = h/kT$, where h is Planck's constant and $k_B$is Boltzmann's constant in units of Js and Joule/Kelvin, respectively, in combination with long-range correlative behavior distinguished by the relaxation time t_{rel}

$$n \propto \frac{k_B T}{h} t_{\mathrm{rel}} = \frac{t_{\mathrm{rel}}}{t_{\mathrm{corr}}} \qquad (A1)$$

The dimension, n, or number of actual degrees of freedom, displays a basic relation between the temperature and the time scales, t_s, in multiples of t_{corr} at the same time providing a constraining relation or boundary condition for the dissipative system evolving at non-equilibrium steady state conditions, $dS = 0$.

A simple connection with entropy can be explained as follows. Noting that the convex function $-x \log x$ has a maximum at $1/e$, one finds that the entropy for a thermal system, with n degrees of freedom, at equilibrium, defined by $S = k \log \Omega$ with Ω proportional to e^n, obtains as $S \propto nk$. A biological system evolving at $dS = 0$ with the entropy change can be divided into two parts, i.e.,

$$dS = dS_{\mathrm{e}} + dS_{\mathrm{i}} \qquad (A2)$$

where dS_{e} is the entropy flux due to exchanges of energy-matter with the environment, dS_{i} the entropy production due to the irreversible processes inside the system. The second law admits $dS, dS_{\mathrm{i}} \geq 0$. Under the steady state condition, $dS = 0$, one might find a negative entropy flux, $dS_{\mathrm{e}} = -dS_{\mathrm{i}}$,

$$\frac{dS}{S} = \frac{dn}{n} = \frac{dt_s}{t_s} + \frac{dT}{T};\ dS_e = -dS_i = -\frac{SdT}{T} < 0 \qquad (A3)$$

The resulting lowering of the entropy, or negentropic gain, serves as the information pathway for protonic transfer of

thermo-qubits, as, e.g., modeled by photon-polariton interactions in a biomolecular system. Hence the conclusion will be that the present scenario, as assumed above, works out of a steady state situation, i.e., $dS = 0$, with the constraining conditions producing deviations from the system at thermal equilibrium, providing negentropic gain or entanglement.

The appearance of long-range correlative information and the derivation of the thermo-qubit have been presented in various articles, see [141,142] and will not be detailed here. Suffice it to say that it refers back to the fundamental equations of quantum chemistry, i.e., the Schrödinger- and the Liouville-Bloch equations, describing the evolution of the system's wavefunctions and density matrices. An important ingredient is the extensions to open system dynamics via the theory of dilatation analytic transformations [143]. The extension provides an important result, i.e., the possible occurrence of so-called Jordan-block singularities, which imparts a biorthogonal scalar product and the transition from a diagonal matrix ϱ to

$$\varrho \to \rho_{\mathrm{tr}} \quad = \frac{1}{\sqrt{n-1}} \sum_{k=1}^{n-1} |\psi_k\rangle\langle\psi_{k+1}| \qquad (A4)$$

where the dimension n is adapted to the boundary condition (A1). At sufficiently low temperatures, the current long-range operation sends a reminder of the celebrated physical mechanism of Off-Diagonal Long-Range Order, ODLRO [144], explaining superconductivity as the correlations between pairs of conducting electrons with the atomic vibrations of the environment. The thermalization mentioned above procedure, leading up to (A4), is subjected to a particular set of unitary transformations that contains specific symmetry relations, including the canonical vectors, exhibiting various prime factor regularities recalling the celebrated Gödel numbering for assigning a syntax for communication, e.g., the thermo-qubit. This thermalized version of long-range order defines the concept of ODLCI or Off-Diagonal Long-Range Correlative Information. ODLCI is consequently a key mechanism for biological communication and the origin of the thermo-qubit syntax.

The interpretation of *Panexperiential Materialism* [14] incorporates the foregoing mathematical structure, integrating the Fourier-Laplace correspondence between conjugate observables in analogy to pioneering quantum mechanics. Notably, the extended energy-resolvent reciprocal relationship with the time-propagator evolution must account for the appearance of higher-order singularities with associated winding numbers, matching the dimension of the Jordan block singularity. It is straightforward to realize that adding a Jordan block of a particular order to a diagonal matrix will not alter the value of the von Neumann entropy. For a more detailed discussion of the modern axiomatization of quantum theory, see [145]. For additional information on general non-Hermitian extensions to quantum mechanical applications in chemical physics, see, e.g., [146]. Hence the conclusion will be that the present scenario works out of a steady state situation, i.e., $dS = 0$, with the constraining conditions producing deviations from the system at thermal equilibrium, providing negentropic gain.

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